LBNE

Colorado State University

LBNE PHOTON DETECTION SYSTEM DESIGN AND PROTOTYPES

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(for the Photon Detection group)

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Outline

- Motivation and Requirements
- System Design
- Prototypes
- Summary

Motivation

While the TPC will provide excellent spatial resolution it is not able to provide the location of an interaction within the drift region

Liquid argon scintillates with a high light output of about 40,000 γ/MeV of deposited energy – in the absence of an external electric field (about 24,000 γ/MeV in the LBNE TPC E-field)

- scintillation light has wavelength of 128 nm in the vacuum ultra-violet part of the spectrum
- 1/3 of the light is emitted promptly within 6 ns, 2/3 comes later with a time constant of 1.6 μs.
- long attenuation length in argon but 90 cm Rayleigh scattering length at λ=128 nm
- Nitrogen contamination quenches late light scintillation (at the ppm level)

Scintillation light can be used to to provide additional information not given by the TPC

- t_0 of interactions in the drift region
- the ability to determine if events originate within the fiducial volume of the detector
- the ability to correct for energy loss during drift
- a trigger for non-beam events
- potential for enhanced reconstruction (useful for overlapping events)

System Requirements and Goals

To meet the physics requirements of the LBNE experiment the PD system needs to meet the following requirements:

Requirements
Event timing (t_0 relative to the TPC) of better than 1 microsecond to determine event position and provide ability to correct track energy
Ability to provide trigger for non-beam events (proton decay, atmospheric neutrinos)
No injection of unnecessary noise into the TPC electronics

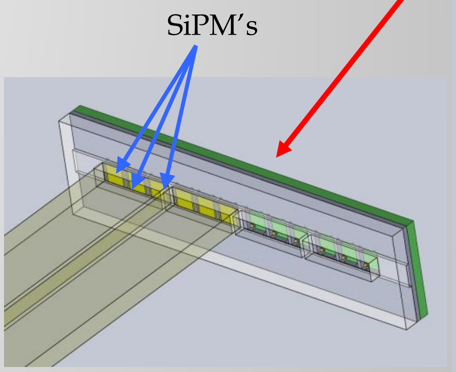
Goals
Ability to provide trigger for supernova burst neutrinos
Ability to detect neutrinos with energy ~10 MeV for SN neutrino measurement

Event timing of better than 1 μs (< 2 mm in event z-position) will be easily achievable

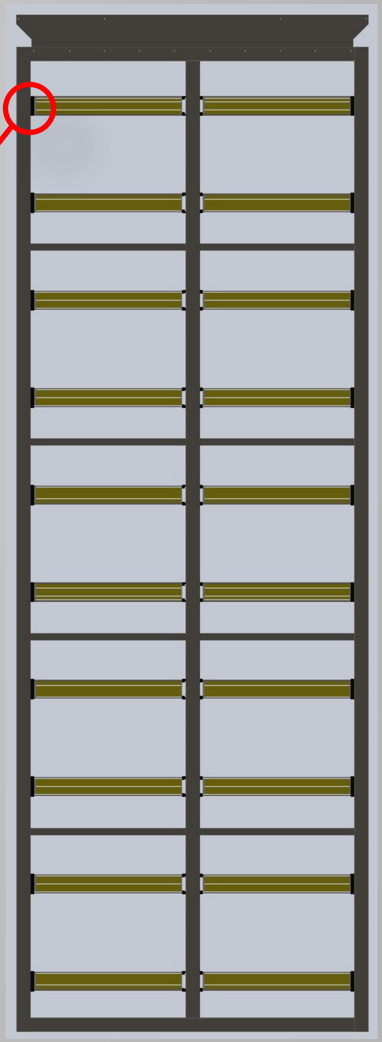
System Design

The photon detection system baseline design is based on plastic bars coated with wavelength shifter, coupled to silicon photo-multipliers (SiPMs), and mounted inside the anode plane assemblies (APA).

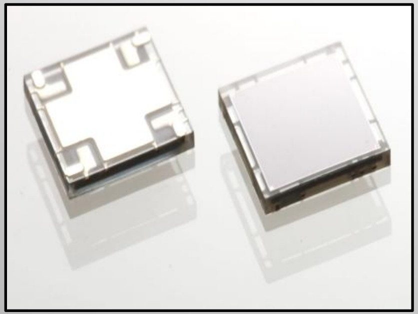
- Plastic bars (6 mm x 25 mm x 1054 mm)
- 4 bars per photon detector (PD)
- 3 SiPMs (channels) per bar
- 20 PDs per APA
- 9600 channels/cryostat for far detector



readout end of paddle



APA containing 20 PDs

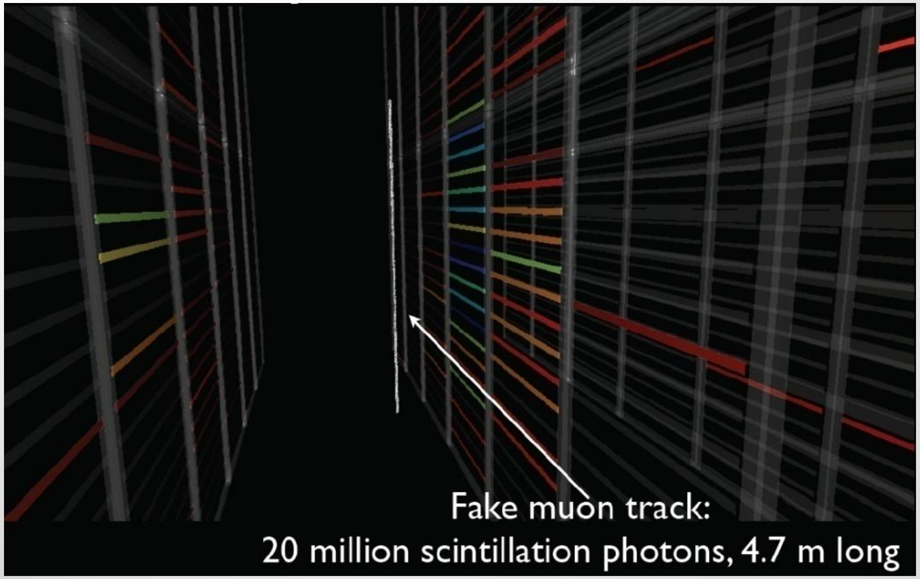


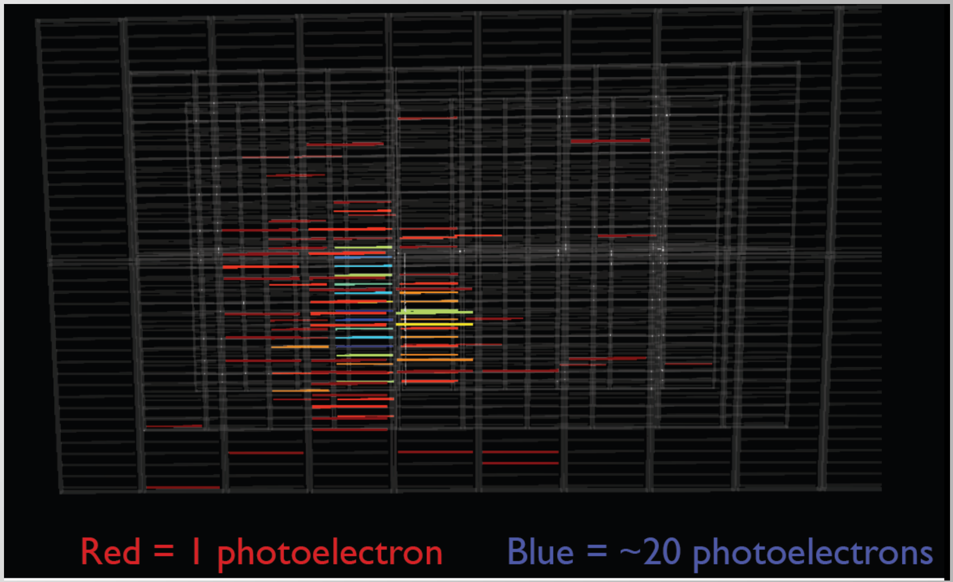
SensL MicroFB-60035-SMT SiPM

- 6 mm x 6 mm active sensor (~19000 microcells)
- 24.5 V breakdown voltage (V_{br})
- peak wavelength 420 nm
- QE 31% @ V_{br} + 2.5 V
- Gain 3E6 @ V_{br} + 2.5 V

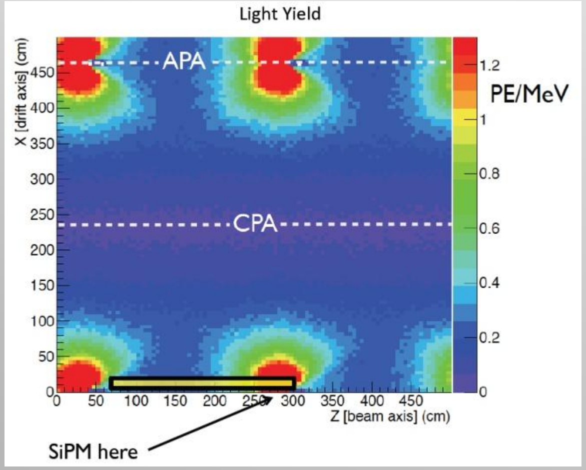
(data at room temp)

System Design





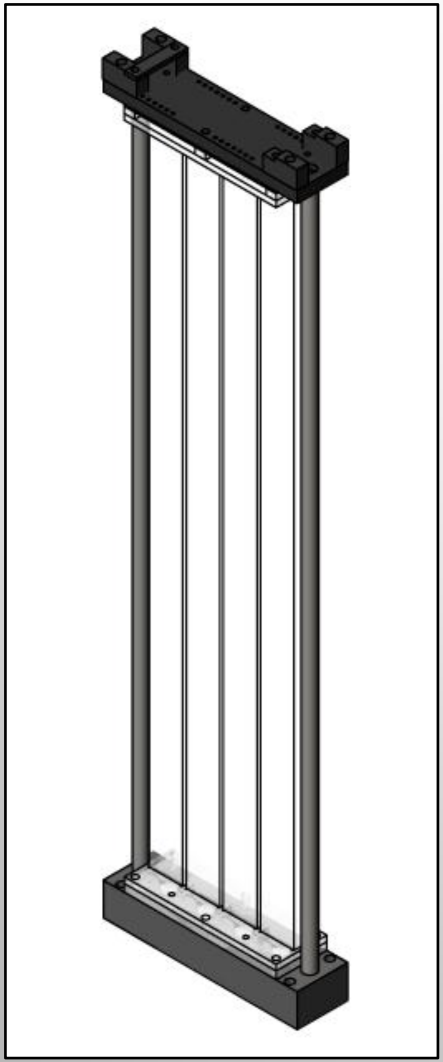
Simulated vertical cosmic muon event showing response of photon detector (stand-alone simulation done by Stan Seibert).



Clearly position-dependent PD system response.

Such dependence could provide information that would feed into reconstruction algorithms

Bar-based Design



Four WLS-doped or coated acrylic bars.

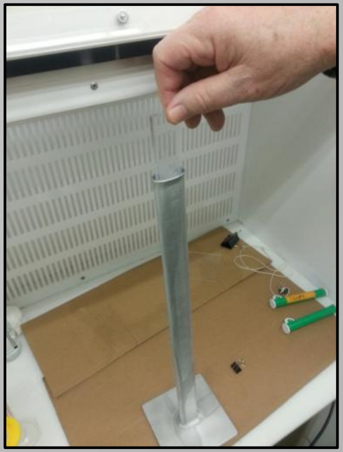
- Each bar couples to 3 SiPMs (72% of bar end couples to active SiPM area)
- 12 SiPMs per PD module

Several coating methods examined (TPB and Bis-MSB)

- Hand painting (with and without heating)
- Spraying and heating
- Dipping (with and without heating)

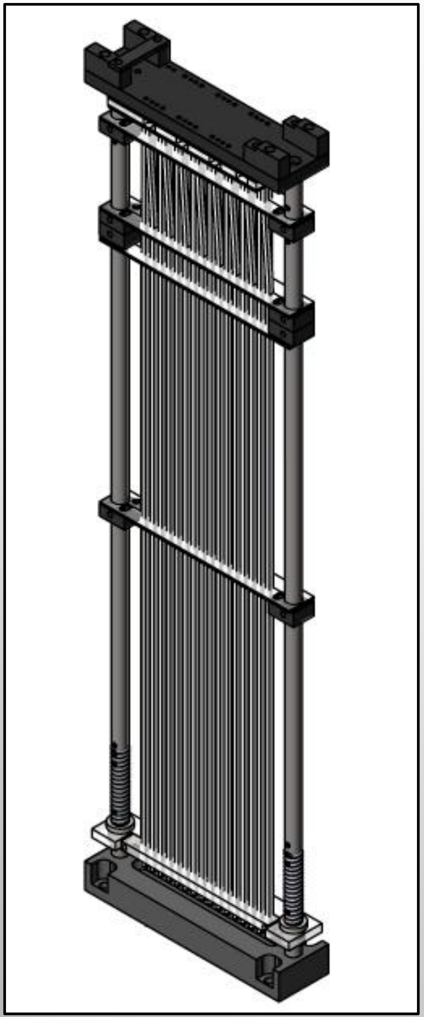
Commercially produced doped bars (TPB only)

4-bar prototype mounted in PD frame



Hand dipping acrylic bar in TPB-based mixture

Fiber-based Design

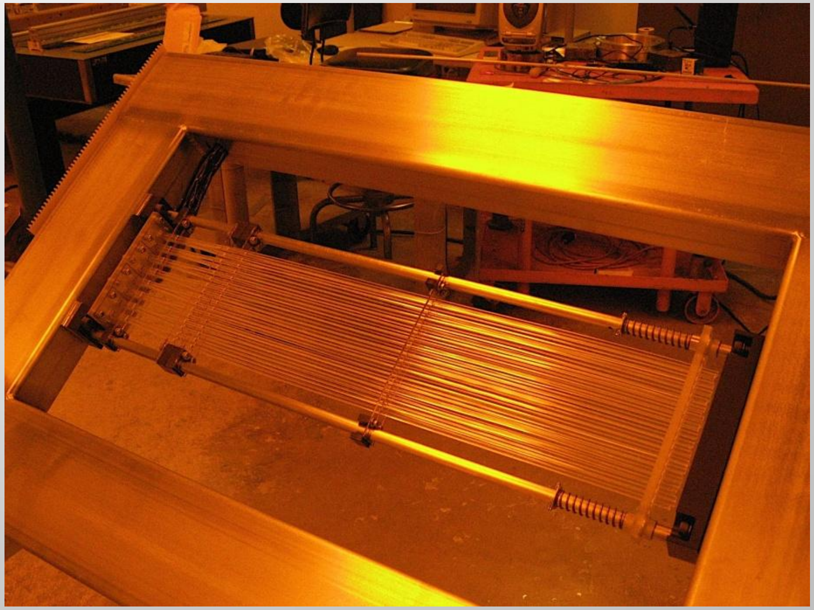


32 WLS-doped unclad square-profile fibers (3×3 mm^2) .

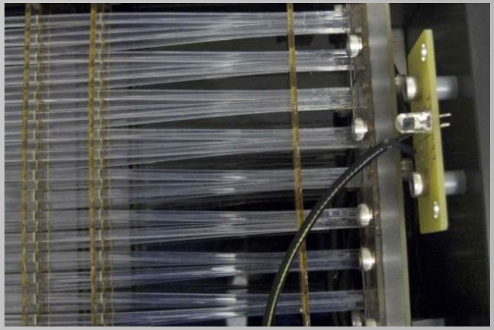
- 100% of fibers couple to active SiPM area (4 per SiPM)
- 8 SiPMs per PD module

Only doped fibers examined (TPB)

- Base is polystyrene due to vendor availability
- TPB doping level is 1% by weight

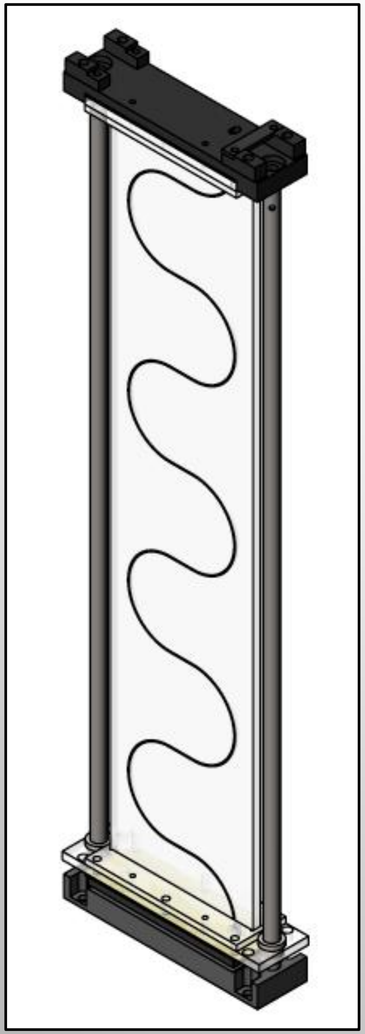


WLS-fiber based prototype mounted into APA for 35t test – orange light due to UV filtration on room lighting



Close-up showing 4-fiber coupling to SiPM (8 such couplings shown in figure)

Fiber-embedded plate-based Design

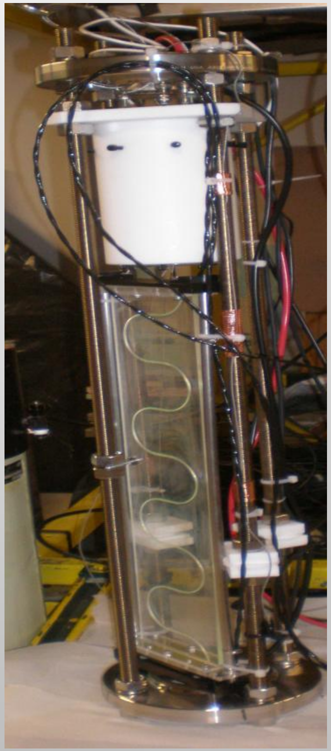


WLS-doped clad Y11 fiber(s) embedded in TPB-coated plate.

- 2 SiPMs used in module (one at each end of fiber)
- Additional fibers can be stacked in groove to increase acceptance

Potential for significant coverage

- low readout channel count leads to large scale-up
- Doped fibers could be optimized to match TPB emission and SiPM QE.



Prototype mounted in preparation for LAr testing.

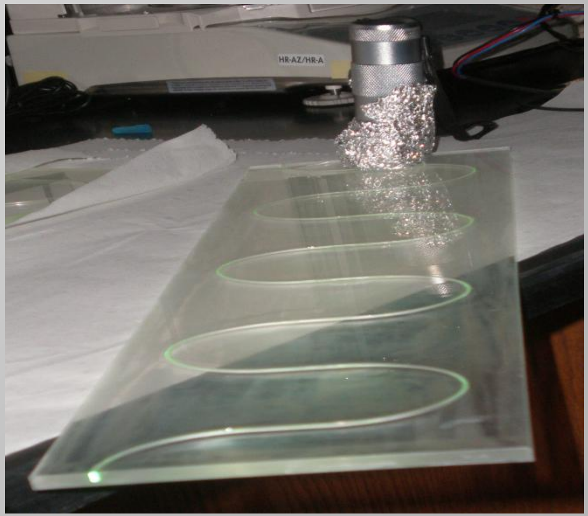


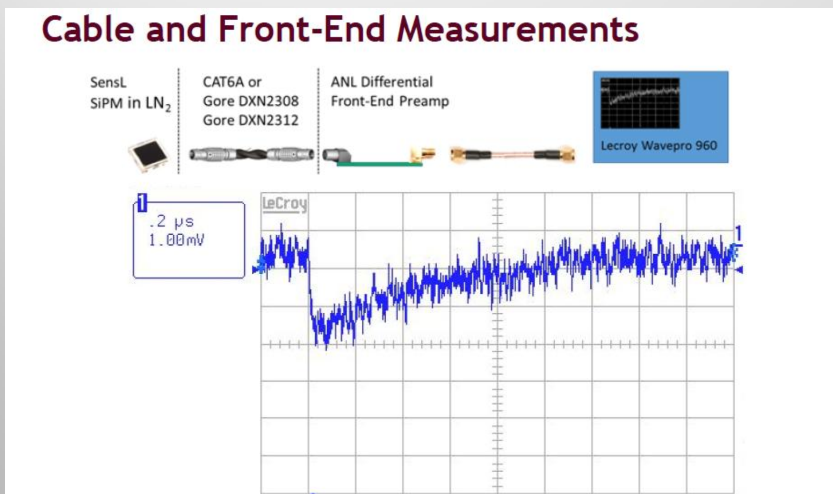
Plate with Y11 fiber embedded (prior to mounting in frame with SiPMs)

Readout Electronics

Readout electronics developed by ANL group

- Single p.e. resolution capable
- 14 bit dynamic range (1.8 V full range)
- timing resolution ≤ 5 ns
- Data buffer length (13 μs) – good late light detection
- System highly configurable

Single SSP (12 channels) in 1U module



Single photo-electron signal, 100 ohm termination, X19.95 amplification, with 2.5E6 SiPM gain. J. Anderson

4 SiPM Signal Processors (SSPs) Completed

- One used for TallBo test earlier this year
- TallBo SSP now located at IU
- One SSP at CSU to be used for testing PD prototypes
- SSP being sent to Oxford to be used in developing board reader for DAQ

8 Additional SSPs being fabricated for 35t test

Summary

- Development of a photon detection system well underway to meet the requirements of the LBNE physics program
- Several prototypes have been designed and fabricated utilizing the baseline bar-based design as well as fiber and plate based designs
- Testing in local small-scale facilities is ongoing (see D. Whittington's talk)
- A large-scale test of the various prototypes will be performed in the FNAL 35-t prototype LAr cryostat next January leading to a technology down-select next summer.